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International Space Station Strategic Roadmap Committee
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The Magnolia Hotel
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Meeting Report Prepared by:
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Opening Remarks

Robert Cabana, a co-chair of the International Space Station (ISS) Strategic Roadmap (SRM) Committee, opened the meeting at 10 am. He asked members and visitors to introduce themselves. Shuttle *Discovery* is rolling to its launch pad in preparation for launch of STS-114 in May. The Flight Readiness Review is being conducted for the next ISS crew (Expedition 11).

The purpose of the ISS SRM Committee, Col. Cabana said in reviewing the agenda, is to determine the uses of the ISS. The first day's effort at this meeting is primarily informational, with the committee receiving briefings. Thomas Betterton, also a co-chair of the SRM Committee, said that the aim for the second day is to spend most of the afternoon drafting material for the roadmap report and reviewing material already drafted. Stacey Edgington, the Designated Federal Official for this committee, reported that the collaborative website for the committee's use should be operational within a day or two. Col. Cabana reviewed the rules for the public meeting in accordance with the Federal Advisory Committee Act (FACA).

NASA and ISS Risk Management Approach

Tony Gallina of the Space Operations Mission Directorate (SOMD) ISS staff briefed the committee on NASA's risk management approach and the risk management activities specific to the ISS. He displayed and discussed a flow chart showing how risk management requirements flow down from Safety and Mission Assurance (SMA) requirements in NASA Policy Directive (NPD) 8700.1 and from program/project management requirements in NPD 7120.4 and NASA Procedural Requirement (NPR) 7120.5. Requirements related to human safety risk requirements derive from Human Rating Requirements for Space Systems, NPR 8705.2A. The ISS Risk Management Plan and the Exploration Systems Mission Directorate (ESMD) Risk Management Plan reflect all of these higher level requirements documents.

Col. Cabana noted that the risk management system adopted by the ESMD, known as Automated Requirements Management (ARM), differs from the ISS Risk Management Application (IRMA) developed within the ISS program. He asked if there had been consideration of adopting one system across the Agency. Mr. Gallina thought there was still opportunity to do that. In his opinion the ISS Program had the most experience in risk management programs. Col. Cabana agreed, noting that IRMA takes into account cost, schedule, and technical risks.

RADM Betterton asked about the distinction between risk management and risk mitigation with respect to the risk management plans. Mr. Gallina said that risk mitigation is a subset of the entire risk management process and activity. Col. Cabana added that every risk identified in the plan must have a risk mitigation action identified for it.

Mr. Gallina next gave an overview of the ISS Program's risk management system and tools. The continuous risk management process required by NASA guidance has a repeating cycle of identifying risks, analyzing them, planning what to do about them, tracking metrics for the risks and mitigation results, and a control step to decide on replanning or other actions. Risk management should include system engineering (configuration management, technical risks, etc.)

and project control (cost/budget, schedule, and work force risks), as well as the safety and environmental risks that are the focus of SMA. In the ISS Program, risk management is implemented by SMA and the ISS Program Risk Office. The key principles of that implementation are to: (1) embed risk management processes into normal day-to-day activities, (2) delegate risk management responsibility to the lowest possible organization with the allocated resources to mitigate or authority to accept the risk, and (3) dedicate a Program Risk Management organization to lead program-level risk management activities. Program-level risk management includes probabilistic risk assessments (PRAs), which focus on managing safety risks, and quantitative risk analyses (QRAs), which are used to manage budget risks. IRMA is the database that supports ISS risk management. Mr. Gallina described how risk management decisions can be transferred from lower-level organizations to higher levels when broader authority is needed to address a risk. PRAs and QRAs are intended to provide additional input to decision-makers, rather than driving to a single-solution outcome. Rather than focusing on the estimated probability of a risk in a PRA as an isolated number, PRA estimates are best used to compare relative risks as part of risk reduction and management activities. Similarly, the probabilistic estimates of cost risk for identified budget threats that are developed in QRAs are categorized into three broad categories of likelihood (greater than 50 percent likely to occur, about 50/50, and less than 50 percent likely). The cost uncertainty factors applied to each budget threat are tuned with historical data from NASA programs. These factors are expected to improve as increasing amounts of ISS operational data are included in the computations.

Concerns in any of the risk areas can lead to formulation of an ISS risk item or a watch item. The top program risks go before the Program Risk Advisory Board (PRAB), which meets every 4–6 weeks. All departments in the ISS Program participate in this process. Mr. Gallina also described how risk management processes are embedded in the ISS Program's contract structure and flow down from the PRAB through the divisions and branch structure to individuals. Each contractor is required to have a risk management program, and each division has a board with risk management responsibilities. The program uses the Capability Maturity Model Integration (CMMI) methodology developed by Carnegie Mellon University to assess the maturity of risk management activities. In his summary, Mr. Gallina said that ISS risk management is consistent with the NASA initiative on risk management. It is a process valued and used by senior program management. It is one of the most mature risk management processes in NASA, even as it continues to improve and be refined.

Discussion: In response to Col. Cabana's suggestion to show how an actual ISS risk is run through the process, Mr. Gallina used an example from his backup viewcharts. Members discussed with Mr. Gallina how the likelihood and consequence ratings for a risk item are determined. Dr. Bartoe said that the definitions for the levels of likelihood and consequence have, with use over time, created a common culture in which users have a shared understanding of a risk's rating. Another important aspect, he said, is the required coupling of each identified risk with a risk mitigation plan. The committee discussed the extent to which the ISS risk mitigation system is used by the International Partners, the role of tracked watch items as a secondary level of risk awareness, mitigation plans associated with risk items, and the representation of uncertainty about a risk. As a summary comment, Mr. Bastedo said that the program has an organized process for identifying and managing risks, with a number of people involved in building a consensus on how each risk is ranked. The committee also discussed the extent to which cost/benefit ratios could provide a metric for the ratio of risk to return on investment and the utility of QRAs for assessing cumulative impact of identified threats to the budget and to schedules.

Dr. Oman and Col. Cabana discussed the IRMA risk database and how it differs from the ARM tool being used by the ESMD. More information about the ARM tool is needed. In response to a question from RADM Betterton, Dr. Oman said that the relevance of the risk management approach to the roadmap may relate to cost/benefit considerations for uses of the ISS relative to other options, as well as to identifying high-risk elements ("hot spots"). Mr. Cabana described the relevance to the ISS SRM as providing a level of confidence that the ISS will be a usable and useful tool to gain knowledge needed for Exploration Initiative objectives. RADM Betterton agreed that the ISS risk management capability could be useful at the higher, programmatic level of cost/benefit and risk reduction considerations for Exploration-related decisions. The committee agreed with Col. Cabana's suggestion to recommend that an integrated risk management approach be part of the integration process for defining the NASA Integrated Strategic Architecture (ISA) from the sets of strategic roadmaps and capability roadmaps (CRMs).

Exploration Transportation Systems Strategic Roadmap

Stephen Cook of Marshall Space Flight Center (MSFC) briefed the ISS SRM Committee on the status of the Exploration Transportation Systems SRM. He said that the Exploration Transportation Systems SRM Committee's broad interpretation of its guiding Strategic Objective has greatly expanded the potential range of space transportation missions being considered for that roadmap's pathways and options. Transportation systems are being considered for robotic and human missions and for destinations including the Moon, Mars, and elsewhere in the solar system. The potential range of space transportation missions thus includes Earth and Earth orbit, Earth neighborhood, accessible planetary surfaces, outer planets of the solar system, and beyond. The staff has been working to prepare for the committee's second meeting, to be held on April 18–19 in the Washington, D.C., area. In response to a question from RADM Betterton, Mr. Cook said that the Strategic Objective is being interpreted to include safe return of cargo to Earth, as well as safe return of the crew. He emphasized that the purpose of the roadmap is not to define a transportation systems architecture but to lay out the key decision points, the options that can feed into those decision points, key questions that need answers before decisions are made, and the potential outcomes from decision alternatives.

The full roadmap will be composed of five themes: (1) transportation from Earth to Earth orbit; (2) transfer to destination orbit and orbital operations at the destination; (3) descent, surface operations, and ascent at destination bodies; (4) destination orbital operations and transfer from destination to vicinity of Earth; and (5) Earth capture and reentry. Dr. Oman asked if the roadmap would cover transportation systems for robotic missions. Mr. Cook said that human exploration missions beyond the Moon would probably require preparatory robotic missions, so the transportation system for a destination could be a system of [spacecraft] systems. The roadmap is being built up with time-phased spirals, with key decision points identified relative to major milestones in each spiral. The questions relevant to the decision points provide the linkage to analysis work that is needed. The SRM staff has developed a 92 x 92 matrix of decisions, options, and critical questions that are intertwined. The 49 critical questions, which support 38 decision points, are organized into categories of policy, capability, architecture element, mission, and campaign questions. To illustrate the linkage analysis, Mr. Cook discussed how the amount of initial mass to insert into low Earth orbit (LEO) affects decisions. He related these linkages to the key possibilities being assessed by the committee for the Earth-to-orbit theme, including the linkages between launch capability and assembly in LEO. This theme includes transportation to and return from the ISS. In response to a question from Col. Cabana, Mr. Cook said that the timing of a heavy-lift vehicle is one of the dimensions being studied. Although pressure is building to make that decision soon, the SRM Committee intends to lay out alternatives, rather than recommending a particular pathway. In response to RADM Betterton's question on potential return endpoints other than Earth, Mr. Cook said the only endpoint proposed for missions in the next 30 years is Earth (including LEO). Beyond that, there may be options to return to a Moon outpost or other endpoint. This point led to discussion of issues in defining the interfaces between strategic roadmaps and integrating them into the ISA.

The first big decision will be whether the Crew Exploration Vehicle (CEV) capability will be used for crew and cargo service to the ISS. There may be a later-generation CEV for Mars missions. Mr. Cook discussed some of the complex interactions and dependencies among pathways for crew transportation, cargo transportation, and ISS servicing. Michael Hawes commented that the Agency will need to make a decision about phasing in a capability to service the ISS earlier than it would be needed for exploration objectives. In answer to a question from Dr. Bartoe about a heavy-lift option derived from the Enhanced Expendable Launch Vehicle (EELV) versus a Shuttle-derived option, Mr. Cook said that the main issue with respect to EELV capability is that it is not currently human-rated. He listed major development options for the EELV-derived and Shuttle-derived pathways. In response to RADM Betterton, Mr. Cook said that the currently planned robotics missions do not have a requirement for a new launch vehicle beyond existing launch vehicles. No transportation development is being considered for robotic missions between now and 2008.

Mr. Cook highlighted the major pathways and decision points in the other four themes of the Exploration Transportation Systems SRM. With respect to transfer to and orbital operations at a destination body, the big question is the role that nuclear electric propulsion (NEP) will play and when it will be ready. A major question for cargo delivery is the degree to which cargo will be predeployed at a destination before the first human mission. The decisions within themes are interlinked and will require a systematic set of architecture studies. The committee discussed with Mr. Cook how the first decisions in the interlinked set might be made. A set of strawman scenarios, reflecting different priorities, will be briefed to the Exploration Transportation Systems SRM Committee at its next meeting. Mr. Cook noted that the analysis has identified 40 circular relationships in the decision network. In response to RADM Betterton, Mr. Cook described the types of information that are being defined as inputs to roadmap decision points.

The linkages to the ISS in the Exploration Transportation Systems roadmap include the ways in which the ISS can serve as a testbed for transportation trade studies and technology development. The ISS is not considered as a potential transportation node for the transportation stage from LEO to transfer to a destination. Dr. Oman asked if the Earth Reentry pathways contained any options that could help with the problem of downmass from the ISS. Mr. Cook replied that there was probably nothing that would be available soon enough. The SRM Committee and staff have not considered return from LEO as a primary driver for transportation system development. He suggested that this may be something to be added to the Exploration Transportation Systems SRM to reflect priorities for the ISS. In response to Mr. Walker, Mr. Cook said that the horizontal bars for concept development and focused technology development activities represent approximate estimates of the starting points and durations of those activities. Mr. Bartoe asked if the Exploration Transportation Systems SRM will identify ways of taking advantage of the ISS. Mr. Cook said that the ISS is in the roadmap in several places as a potential feeder for information needed to support a roadmap decision, but the ISS SRM Committee should identify what it thinks the ISS can support in the Exploration Transportation Systems roadmap. This exchange led to further discussion of how best to establish the support relationships between the two roadmaps and interdependencies with the CRMs. Mr. Cook described how his SRM Committee has been working with specific CRM teams, such as the In-Space Propulsion CRM team. In response to a question from Mr. Walker about engineering representation on the NAS/NRC review panels, Mr. Hawes said that the review panels will have members from both the Space Studies Board and the Aeronautics and Space Engineering Board, as appropriate to the science and technology addressed in a particular roadmap.

Robotic and Human Lunar Exploration Roadmap

Mr. Hawes began his presentation on the status of the Lunar Exploration SRM with comments on the need to surface the interconnects among the SRMS and CRMs and address them as part of the integration effort. In discussing the guiding Strategic Objective for the Lunar Exploration SRM, he noted that it must take into account the transition into human exploration missions to Mars. As part of the rationale for its roadmap, the Lunar Exploration SRM Committee has defined a set of specific roadmap objectives in three categories: (1) to advance scientific knowledge, (2) to develop new approaches to support sustained human exploration to Mars and other destinations, and (3) to advance national interests. The committee has been considering four architecture options, which are emerging now as four pathways in a larger unified roadmap in which decision points branch to major pathways representing the four options. The options vary with respect to the sustainability and permanence of the outpost(s) established on the Moon and the extent to which the transition to Mars exploration leads to cessation of NASA activities at the lunar outpost. A follow-on action for the staff from the latest committee meeting is to combine the four options into a decision tree with branches. The options will be rated against the Strategic Objective and the roadmap-specific objectives at the third committee meeting.

In Option A, the focus is on building up a lunar outpost to prepare for Mars missions, with a set of precursor robotic missions to characterize potential landing sites. For this option, human sortie missions are necessary to select the outpost site. Lunar activity ramps down quickly once the technology for a human Mars mission is considered ready. Mr. Hawes described the in situ resource utilization (ISRU) and outpost facilities that are part of this option. In response to Dr. Bartoe's question about technology demonstrations in LEO shown in the Option A roadmap, Mr. Hawes said the demonstrations might use the ISS or an early CEV capability. The lunar outpost is not assumed in the roadmap to be in a lunar polar region.

In Option B, the lunar outpost is selected without human sortie missions to multiple candidate sites because the information from the robotic precursor missions is sufficient to make the selection. The model for the outpost in this option has a hub site with specialized outposts at distances that can be traversed easily with ground systems. Option C emphasizes early development of lunar ISRU for commercial exploitation. Ultimately, the lunar settlement would be operated by commercial interests, with the U.S. Government as the initial customer. Market-driven customers would come later. A commercial communications and navigation network supports commercial robotic missions as well as commercial lunar habitation and surface activities. A Commercial Subgroup to the Lunar Exploration SRM Committee has been developing content for Option C. Option D is focused on an expedited transition from lunar exploration to human missions to Mars. A minimalist lunar outpost is used primarily to demonstrate capabilities needed to proceed with human Mars missions. The lunar outpost is used to buy down the risk of Mars exploration. In response to a question on the apparent timing of the transition to Mars missions in the draft roadmap, Mr. Hawes explained that the paths are still notional at this point and are meant to show the ordering and phasing of activities and capabilities, rather than solid timing of milestones.

When asked if the Lunar Exploration SRM Committee had thought about the pushback from lunar activities to space transportation capabilities, Mr. Hawes said that the discussions had not dealt much with that. A major challenge of the integration will be to identify and incorporate the linkages across the SRMs. RADM Betterton said that the four options do not present any compelling need for the ISS. Mr. Hawes replied that the committee has not made any judgments on the value of the ISS to the pathways. The LEO demonstrations, for example, could be done either on the ISS or by another means. A study is in progress to assess where specific technology demonstrations are best done (e.g., on Earth, in Earth orbit, or at the Moon). The ISS as a test venue plays more heavily in that study. A similar study of demonstration venues, including the ISS specifically as a test venue, is being done for the Robotic and Human Exploration of Mars SRM. Mr. Hawes described in general terms the focus of the Mars SRM and its rationale for a key linkage to heavy-lift capability in the Exploration Transportation Systems SRM. A subgroup of the Mars SRM Committee is examining technology requirements and their linkages back to demonstrations on the Moon and on the ISS. Barbara Kreykenbohm noted that the National Academies/National Review Council (NAS/NRC) review panels have been stressing the importance of human–robotic interaction in exploration missions. Mr. Hawes added that a subgroup of the Lunar Exploration SRM Committee has been established to investigate human–robotic capability on the Moon. Mr. Walker said the lunar option pathways did not explicitly reference decisions on space transportation systems, which he thought would affect the choice among the pathways. Mr. Hawes replied that the Lunar Exploration SRM Committee heard an overview on transportation system trade studies at its first meeting but concluded that the options involved were not primary drivers for the lunar roadmap alternatives.

Human Health and Support Systems Capability Roadmap

John Charles from the JSC Life Sciences Directorate started with a presentation on human health risk management, space medicine, the *Bioastronautics Roadmap*, and risk quantification. He described the current practice used by NASA space medicine personnel to assess risks and outcomes based on historical and current data. Current findings come from the Patient Condition Database and the JSC Longitudinal Study of Astronaut Health (LSAH). Polk and Duncan are developing an assessment matrix that rates severity of consequences from a health-related event during a mission with a *qualitative* assessment of the probability of that event. The *Bioastronautics Roadmap*[1] resulted from an assessment of identified risks in long-duration missions. After reviewing the goal, objectives, and target audiences of the roadmap, Dr. Charles presented a flow chart for the process by which it was developed. The reference missions on which the roadmap's requirements were based included a nominal 1-year ISS mission, a 30-day Moon mission, and a 30-month Mars mission. A set of parameters, characterizing the crew exposure conditions anticipated for these reference missions, was distributed widely in the relevant science community as the basis for identifying health risks of long-duration spaceflight. The categories of deliverables that were considered useful roadmap outcomes included knowledge gains, standards, requirements, countermeasures, diagnostic and treatment tools, training and credentialing, in-flight medical protocols, design tools, technologies, and components or subsystems for use in missions. The community process identified 45 risks, for which the team developed a risk rating methodology. This risk rating uses three priority levels for human health risks and three levels for system performance and efficiency risks. The health and medical issues that received high priority for the Mars reference mission included radiation protection, autonomous medical care, bone loss, sensory motor capability after landing on Mars, nutrition, and environmental contaminants. External drivers on the risk reduction strategy presented in the roadmap include the Shuttle retirement in 2010 and completion of NASA's commitment to the ISS by 2016. To resolve all the risks identified in the roadmap would require analysis of 200 (±30) ISS crewmembers as human research subjects. Since that number of crew will not be possible, not all of the risks can be fully resolved. Although there are mitigation plans

[1] Document No. NASA/SP-2004-6113; available online at http://biastroroadmap.nasa.gov/index.jsp.

for all of the risks, the lack of full resolution will mean greater uncertainties on the effectiveness of the mitigations. For example, proposed countermeasures must be demonstrated in mission-like conditions before they can be known to be adequate. Dr. Charles discussed with the committee the bed-rest model for bone loss in weightlessness as an example of the limitations of alternatives to ISS-based testing. At present, he said, many of the risks for the 30-month Mars mission are at priority level 1 (highest of the three), and the goal of the roadmap is to lower them to at least level 3 risks. By contrast, the health risks for a 1-year ISS mission are all at levels 2 or 3, except for a couple at level 1. All of the roughly 15 system performance and efficiency risks are at risk level 1 for the 30-month Mars mission. The roadmap team also developed a four-level rating scale for the priority of doing research on the ISS (as opposed to adequacy of other test venues such as laboratory testing). Dr. Charles summarized the results of applying this ISS test venue prioritization to the identified risks of long-term spaceflight.

Dr. Charles next described efforts to apply something akin to a PRA methodology to move toward quantification of spaceflight health risks. An ISS PRA exists already, and an effort is under way to add health and crew performance aspects to it. The program scientists are interested in expanding this PRA approach to cover future spirals in exploration missions. The team working on this quantification effort includes physician astronauts, flight surgeons, and discipline experts. The approach will be attempted first with some better-characterized risks such as bone loss, to assess its feasibility. In response to a comment from Dr. Bartoe on availability of historical data to perform quantitative risk analyses, Dr. Charles contrasted retrospective studies in highly constrained settings with the prospective and predictive challenges in quantifying the risks identified in the *Bioastronautics Roadmap.*

The second part of Dr. Charles' presentation was a status report on the Human Health and Support Systems CRM. The capability breakdown structure used in this CRM has three major subcapabilities: human health and performance, life support and habitats, and extravehicular activity (EVA). The category for human health and performance includes capabilities to address space radiation, medical care, human health countermeasures, behavioral health and performance, and space human factors. Under each of these topics, the CRM team identified specific capabilities for which the ISS or other spaceflight platform has great value as a testbed (labeled "required") and those for which it has substantial value (labeled "highly desirable). RADM Betterton asked how useful test results now on something like medical devices would be in 2035, given the rate of technological advances. Dr. Charles replied that such results would still provide a baseline of knowledge. There was general discussion of the extent to which the time gap between ISS-based testing and application in a human Mars mission would limit the tests' value.

Returning to the presentation viewcharts, Dr. Charles said that Shuttle and ISS standards and practices are the primary source for the state of the art in human health and performance capabilities. Terrestrial medical applications and DOD standards and practices are secondary sources. With respect to medical care, which includes medical devices, clinical capabilities, and medical informatics, the ISS Crew Health Care System provides capability to stabilize and transport crew members. The Medical Care Roadmap (within the Human Health and Support Systems CRM) specifies research and testing that could be done on the ISS as a function of Exploration Initiative spirals. The CRM includes a listing of countermeasures in various stages of maturation from development through validation to operational use. The countermeasures area is the one with the greatest need for ISS development, and Dr. Charles discussed the status of countermeasure validation relative to needs identified for a Mars mission. The strongest case for the ISS with respect to human health research, he said, is as a platform to develop a validated countermeasure suite for Mars before 2016, when the ISS is no longer available. The alternative to validating the countermeasure suite on the ISS is to accept the risk and attendant uncertainties.

In the area of artificial gravity methods, Dr. Charles said a major issue is whether the gravity experienced during surface operations on the Moon or Mars will suffice to prevent the crew from losing operational capability. The Centrifuge Accommodation Module on the ISS could help to resolve this issue. With respect to alternatives to use of the ISS, Dr. Charles and the committee discussed the International Multilateral Artificial Gravity (IMAG) study. Dr. Charles briefly reviewed the contents of the Behavioral Health and Performance Roadmap and the Human Factors Roadmap portions of the Human Health and Support Systems CRM. For the human health and performance category, the roadmap includes a list of the ten most important capabilities. Dr. Charles said the ISS (as a research and demonstration venue) is obviously a good match to this set of priority capabilities. Dr. Charles concluded his presentation with a quick overview of the Life Support and Habitation and Advanced EVA Systems sections of the Human Health and Support Systems CRM.

ISS Education Outreach

Ford Dillon of the ISS External Relations Office began with a sample of education and public outreach (E/PO) activities in which the ISS is specifically or uniquely involved. Barbara Kreykenbohm commented that the E/PO section of the ISS SRM should show how E/PO involving the ISS will support NASA exploration. In the area of formal education (teaching) activities, Mr. Dillon gave past examples of inflight and ground events involving the ISS and astronauts. As part of the Education Payload Operations program, ISS crew members demonstrate basic principles of science, math, engineering, and geography. The Amateur Radio on the ISS (ARISS) program involves ham radio contact between ISS astronauts and students for a 10-minute question and answer session.

Marlene MacLeish, the liaison to this SRM Committee from the E/PO SRM Committee, said that a requirement on the E/PO SRM is to evaluate current E/PO activities as drivers for NASA objectives. For this purpose, the E/PO SRM Committee is seeking objective data showing long-term educational benefits for the students who participate. Mr. Dillon said that the ISS External Affairs Office has viewed its programs in terms of sparking the interest of individual children, but it has no quantitative measures of long-term educational impact. Dr. MacLeish offered further suggestions on the types of compelling arguments that are needed for the E/PO SRM.

Mr. Dillon continued with examples from the ISS Engineering Outreach program to high school and community college students and examples from the Educator Resource Center Networks. Dr. Oman asked if the advent of ISS development had changed NASA E/PO from what was done previously—for example, with the Space Shuttle. Will it change again, he asked, as ISS operations change? In response to another question, Mr. Dillon said that some of his first examples of ISS-related education events were ISS unique, others combine Shuttle and ISS involvement and are run by JSC , and some are run by the SOMD from Headquarters.

ISS Capabilities for Exploration

William Gerstenmaier, ISS Program Manager, addressed the ISS SRM Committee by telephone, with an accompanying viewchart presentation. Many of the ISS subsystems, he said, can be used as testbeds for exploration technology, procedures, and prototypes. Examples include the Regenerative Environmental Control and Life Support System (ECLSS) and real-time in-station atmosphere monitors, which are under development or planned for acquisition for the ISS. He would like to team with the ESMD to build this replacement/enhancement equipment to specifications that would meet future exploration requirements. The hardware would be flown to the ISS and used there, as part of a rigorous operational check-out. Mr. Gerstenmaier described other examples in areas of automation and robotics, sensors and manipulators, propulsion subsystems and components (e.g., advanced propulsion ion thrusters), solar energy arrays and components, and lithium-ion battery technologies. He would also like to align the ISS supply line for logistics and resupply with exploration needs. An example is sold-state lighting, which will be used to replace lighting units in the ISS that are burning out. Specifications for use of these lighting units at the Moon and Mars are being incorporated in the ISS acquisition. There will be years of runtime on the lighting units before a commitment must be made for using them on the Moon or Mars.

RADM Betterton asked about major ISS reconfiguration changes to support exploration needs. Mr. Gerstenmaier said that at present he is redesigning systems anyway because the Shuttle will be phased out in 2010. For example, replaced units will need to be disposable, rather than being returned to the ground and refurbished for reuse. The ISS maintenance approach is also changing, based on the past two years' experience. This change includes more emphasis on inflight repairs inside Orbital Replacement Units (ORUs), such as repairing control moment gyroscopes. However, cooperation from the ESMD on these alignment opportunities has been limited, in part because the ISS Program needs hardware soon, while the ESMD is still in the concept phase. In some of these areas, Mr. Gerstenmaier believes the ISS Program will have to lead ahead of ESMD requirements. In answer to a question on the reception from the ESMD to the range of ideas Mr. Gerstenmaier had just discussed, he said the ESMD does not see a need to align with ISS activities. They are more concerned with being constrained if the ISS is on their critical path. In some areas such as atmospheric monitoring, the ISS Program has established pooled funding with the ESMD counterpart personnel to build hardware that meets needs for both programs. So there have been some small successes in limited areas, but not broad receptiveness at a higher level. Particularly at the middle level in ESMD, the focus is on how to develop high-level requirements for the CEV and other upcoming acquisition activities. Mr. Gerstenmaier said he can understand that their present focus is on higher-level problems than solid-state lighting units, but if they could provide some guidance, he would be willing to move out in advance of final requirements. His concern is for the ISS Program to provide what it can in support of the Exploration Vision.

Ms. Kreykenbohm suggested that a request could be made to the CRM teams to provide input on capabilities development or testing needed from the ISS. Mr. Gerstenmaier agreed and said he could match that list against his list of areas where he thinks the ISS Program can help. Some of the possibilities are not mandatory, he said, but they could provide substantial risk reduction benefits. Ms. Kreykenbohm said that the NRC reviews of the draft CRMs have noted the importance of automated rendezvous and docking, with the ISS tests of that capability being an example to pursue. Mr. Gerstenmaier replied that the ISS Program will be developing and testing two different automated rendezvous and docking techniques, one for the European Automated Transfer Vehicle (ATV) and another for the Japanese H-II Transfer Vehicle (HTV).

In reply to a question on impact of the loss of the Shuttle's lift capability after 2010, Mr. Gerstenmaier said that the impact, which will be reflected in the FY 2006 budget, is not as large as the program first thought it might be. Some ORUs will need to be redesigned to not require the Shuttle. With respect to the impact on ISS support of research, an unknown is that external hardware on the truss has not been activated yet, so failure rates on those items are not known. If the predicted failure rates turn out to be realistic, providing spares will provide considerable upmass competition with research utilization of the ISS. The science downmass requirement has been scrubbed pretty well (as part of the response to the Shuttle stand-down), and there is little science downmass. Replaced hardware will be disposed of in space, rather than flown down. The same approach has been taken with science experiments, in which racks, hardware, and materials will be burned up in the atmosphere, rather than being flown back to Earth. Dr. Oman asked if the logistics model for the ISS is up to date and provides margin for ISS utilization. Mr. Gerstenmaier said the upmass margin for utilization is still limited beyond 2010. The research group, now in ESMD, has cut down on its science upmass requirements. Maintenance schedules are being updated to use actual failure rates in place of predicted rates, but the problem remains of establishing failure experience for the new hardware. Time is needed to let the logistics requirements mature. Mr. Walker asked if any of the International Partners have come to NASA with ideas on how they could use the ISS for exploration-related activities. Mr. Gerstenmaier replied that the International Partners have not adopted the Exploration Vision as fully as NASA has. They would prefer to proceed with their previous purposes. In response to a question from Dr. Lomax, Mr. Gerstenmaier said that his term "advanced life support systems" includes oxygen supply, carbon dioxide contaminant removal, monitoring, etc., while "advanced habitation systems" includes exercise devices, sleep stations, and other things associated with living someplace.

Mr. Gerstenmaier continued with examples of ISS areas of applicability to exploration. Areas of the ISS can be used to test new approaches to radiation protection, noise protection and reduction, control of static electrical charging/discharging, and meteoroid protection. In the area of advanced power systems, it will be difficult to fly unique test articles that have substantial upmass, but if replacements need to be flown up anyway, they could be upgraded or altered to reflect exploration-driven purposes and requirements beyond what is specifically required for ISS operation. In the area of testing operations concepts, the ISS Program will try operating the ISS for a full day with no ground commands, to see if the ISS and crew can operate autonomously. Management and upgrade of large quantities of software at a remote location is another operational aspect that can be tested on the ISS. In concluding his presentation, Mr. Gerstenmaier said that NASA has a unique opportunity for technical and acquisitions collaboration across the two largest NASA programs: Space Exploration built on the foundation and experience of the ISS Program.

Questions: Mr. Bastedo agreed that the ISS is potentially valuable for gaining knowledge useful to exploration, and he asked about mechanisms in use for systematic capture of that knowledge. To provide for direct transfer of knowledge, Mr. Gerstenmaier would like to have personnel from exploration programs participate in the ISS Program. Participating in councils, maintenance operations, and software upload operations, for example, is a more useful way than databases and volumes of documents to learn lessons from ISS experience directly applicable to writing exploration requirements. Dr. Lomax noted that most of the staff in the ESMD requirements division came from JSC and KSC. They are rotating in and out. Mr. Gerstenmaier said he would like to make that process more specific, targeting specific operational areas for rotations. The next series of eight Shuttle flights will be the most complex ones to be done and will provide useful lessons on what works well or not. He thinks the number of Shuttle flights for ISS Assembly is probably near the high end for any on-orbit assembly program. Dr. Bartoe agreed with the wisdom of ensuring that ESMD requirements writers participate in ISS activities to gain experience, but he did not see that as sufficient in the long run. He suggested that the standard practice of the science community needs to be followed: writing the knowledge down and requiring that the next generation learn it. Mr. Gerstenmaier agreed that this needs to be done, but said he did not know how to do it.

In response to Mr. Bastedo's question on plans for ECLSS beyond the Regenerative ECLSS for the ISS, Mr. Gerstenmaier spoke about difficulties in maintaining and operating the current ISS system provided by the Russians. He said that even the Regenerative ECLSS is likely to have a high maintenance requirement. There is a need for research on a generation beyond the

Regenerative ECLSS. Another example is the intensive preventive maintenance being done on the treadmill system. As examples of the limitations of ground testing for such systems, Mr. Gerstenmaier cited components that did not exhibit corrosion and microbial growth problems during ground testing but have had those problems on the ISS. The ISS experience has produced lessons to learn about many subtle things that could become major surprises for lunar or Mars activities if they not taken into account beforehand. There will also be some differences between the zero gravity environment on the ISS and low-gravity fields on the Moon and Mars. For example, an ECLSS for those low-gravity environments could be simpler than the Regenerative ECLSS design for zero gravity.

RADM Betterton asked about the program's planning beyond the near term to the outyears prior to 2016. Mr. Gerstenmaier said that many systems on the ISS can last much longer than 2016, and structural testing will be done to assess structural life. Although the plans now include disposing of the ISS after 2016, nothing is being done in the near term that will force termination then. He thinks that the decision will depend on whether the ISS is providing valuable services as a testbed, in buying down risk for exploration missions, and in doing research. If not, then a plan for disposing of the ISS is in the plans and processes. RADM Betterton asked about robotics systems on the ISS that could support exploration after 2016. In response, Mr. Gerstenmaier noted the lift penalties in launching from the Earth to the ISS orbital inclination, then in launching from the ISS to the Moon. Mr. Bastedo said that, nevertheless, using the ISS as a transportation node for exploration missions provides a lot of operational flexibility. Mr. Gerstenmaier agreed but said that trade studies would be needed on the energy/mass penalties versus the extra flexibility.

Discussion

RADM Betterton asked the SRM Committee members for comments on the presentations and discussions so far during the meeting.

Jeffrey Sutton suggested that, as preparation for the drafting activity on the second day, it would be useful to consider how the information presented could be used constructively in the roadmap. For example, what are the highest priorities for this committee to consider? One of the top priorities, he said, is the linkages with the other SRMs and the CRMs. Ms. Kreykenbohm added that charts showing decisions that need to be made will be useful. RADM Betterton said that Mark Uhran would review specifics for the roadmap content with the committee on Friday morning, including a review of major decision points to incorporate in the roadmap. The committee discussed the appropriate level and number of decision points to use in the roadmap.

Charles Oman asked if the 2010 date for terminating Shuttle and the 2016 date for terminating ISS are real constraints and how they were decided, as they set the framework for the roadmap.

Charles Walker agreed with the prior comments and emphasized the point that the ISS is the only extended-duration, in-orbit operating infrastructure for learning from experience, as well as executing scientific research and technological testing. This capability must be utilized in the planning for exploration missions. The committee should find ways to be assertive about that.

Terri Lomax said that the graphical representations used for the Exploration Transportation Systems SRM worked well. She thought that something like that for the ISS would be the most valuable product for the committee to produce. It could also be readily tied with the Exploration Transportation Systems roadmap. She also said that better communication is needed between the ESMD and the ISS Program. The leadership in ESMD appears to have resonated with Mr.

Gerstenmaier's efforts, and timing seems to have been the primary obstacle. The Level 1 requirements for the time-critical exploration systems programs are now released. Now that the ESMD staff is going to the next level down and looking further out in time, there should be opportunity to get the right people in the two program organizations working with each other.

William Bastedo said that what has been identified so far in the presentations have been technology maturation and demonstration requirements. This SRM Committee cannot go much beyond that until it knows what the other SRMs need, as the path forward for the ISS depends on decisions made by the other SRM Committees. The task is not hopeless, but it is difficult. In short, integration across the SRMs and the CRMs is in the critical path for defining what should be done on the ISS.

John-David Bartoe said that he had hoped the committee could downselect from the Exploration Transportation Systems SRM a list of things to be done on the ISS. Unlike the other SRMs, the ISS roadmap is a present-day roadmap, not a long-term, futuristic roadmap. However, an actual downselect of ISS-based activities from other roadmaps will probably not be achievable within the committee's duration. Therefore, the principle of downselecting from what other activities need must be a principle incorporated into the ISS roadmap as a continuing process by which ISS program content is shaped over the remainder of the ISS lifetime. The roadmap also needs a mechanism to preserve opportunities for other ISS-based projects and activities to be added later. He is concerned that there is not sufficient justification, with respect to the Agency's current goals and objectives, for what is being done now on the ISS. Dr. Lomax agreed with the approach of incorporating a downselect mechanism in the roadmap, with continuing opportunity to respond to needs of exploration programs. She said that the current set of research activities for the ISS does reflect a careful realignment with exploration requirements; this was done during the past year. RADM Betterton said he was not sure at what level one would list the full set of potential activities from which to select. Should categories of research be downselected? Dr. Bartoe suggested beginning with the 45 human health risks identified in the *Bioastronautics Roadmap* and downselecting to those which are most important to address during the lifetime of the ISS, eliminating those risks that can be addressed without the ISS. The roadmap can then lay out an approach to accomplish what is essential to be done by 2016. Discussion of this topic led to agreement that the *process* for making the selection of health risks should be what the roadmap proposes for the ISS Program. The committee should not attempt to select the ISS-essential risk reduction activities now and lay out a detailed program in the SRM to achieve them.

Stacey Edgington suggested that Mark Uhran's presentation on roadmap structure and content in the morning should provide a good framework for the committee to follow. Marlene MacLeish said that she would need some material on the interface between the ISS program and E/PO activities to take back to the E/PO SRM Committee. After a review of the next day's agenda and logistics for the committee dinner in the evening, RADM Betterton adjourned the meeting for the day.

Friday, April 8, 2005

Opening Remarks

Mark Uhran, the third co-chair for the ISS SRM Committee, described the Flight Readiness Review for Expedition 11 on the ISS, which went very well. The schedule for Expedition 11 includes the 10 Soyuz launch, two Progress missions, two Shuttle missions, and eight EVAs. This activity level represents a return to the level prior to the loss of *Columbia*. April 12 is the confirmation hearing for Dr. Michael Griffin as NASA Administrator, and he may be officially in his new position before the end of April. Decisions to be made after the new Administrator is in place include the research plan for the ISS, based on an assessment of the research scenarios prepared by the ESMD. The options represented in the scenarios could have major effects on the ISS Program's industrial, international, and workforce relationships. A second major question is transportation to and from the ISS after the Shuttle retirement.

The schedule for this SRM Committee is less definite now than at the first meeting, Mr. Uhran said. The schedule for completing the roadmap will be delayed because the research plan for the ISS needs to be decided first. The briefings yesterday on other relevant SRMs and CRMs provide an opportunity to see how those committees are approaching issues that are important to formulating the ISS SRM. Similar patterns of event dependency are emerging for several other SRMs. The NASA Advisory Council (NAC) workshop in August and the FY 2007 budget submission are endpoints for the roadmapping process that cannot slip, so products from the roadmapping teams need to be ready to feed into those efforts. After this meeting, Mr. Uhran believes the committee will have the pieces it needs to construct an executable roadmap. The committee's input on an executable plan that has budget, program, and schedule aligned will probably be its most important product. Working on that input will be the focus of the day's activities, after the briefing from the Chief Health and Medical Officer (CHMO). A tentative third meeting date for the committee has been reserved around the projected launch date for the Shuttle. (The committee discussed options for its third meeting later in the day.)

Col. Cabana said that final viewcharts from the Integrated Space Operations Summit will be provided to the SRM Committee members shortly after this meeting. The analyses in the ISS presentations reflect the prior set of requirements. The ISS Program is still waiting for the final science requirements from the ESMD, which will be used to update to a post–Exploration Vision plan. Among the findings from the summit are that the ISS is an excellent engineering testbed for systems needed to go back to the Moon and on to Mars. It will also be an excellent scientific testbed. Col. Cabana believes that, if the requirements for ISS utilization can be defined, the program can find a way to meet them. The SRM Committee will need to help identify what those requirements should be.

Mr. Uhran described the speech made by Dr. Neil Tyson of the Hayden Planetarium for the Goddard Memorial Dinner on April 1. Dr. Tyson's thesis was that increasing the NASA budget stimulates the nation's entire science and engineering educational process, which in turn provides the innovation that drives the nation's economic productivity. In this light, Mr. Uhran emphasized the engineering achievement represented in the ISS. As an agency, he said, NASA does not give sufficient attention to that achievement.

Perspective of the NASA Chief Health and Medical Officer

Richard Williams, NASA Chief Health and Medical Officer, began by comparing the responsibilities of his position, which now acts as the Independent Health and Medical Authority for the Agency, with the role of the Office of the Chief Engineer as the Agency Independent Technical Authority. The health and safety function of his office parallels in some ways the SMA function of the Office of Safety and Mission Assurance. Another aspect of the office is to provide an "internal regulatory" function for space activities that is analogous to some of the regulatory functions performed by the Occupational Safety and Health Administration (OSHA), Food and Drug Administration (FDA), and Environmental Protection Agency (EPA) for the nation. All of the standards for astronaut selection, retention, and qualification are produced by an infrastructure at JSC that is linked by policy directive to the CHMO. The CHMO provides oversight of health care throughout the Agency through biennial audits of the Centers and has responsibility to review and maintain the competence of the medical staff in delivering health care to NASA employees. It also oversees the health and professional development of the flight medicine staff. The CHMO provides full medical care for the astronauts and occupational health and safety services for all other NASA employees. The health of crews and of the entire NASA workforce is the first priority of the office. It also has responsibility for oversight of research, protection of human subjects, and medical risk management as the Independent Health and Medical Authority.

Until a few years ago, Dr. Williams said in discussing the context for life sciences at NASA, the Agency operated under a science imperative as a research organization. In that context, lines of research in the life sciences were broad-based. The chief mechanism for funding research was open competition through Announcements of Opportunity (AOs) and competitive peer review. As of January 2004, this context changed to a focus on supporting the Exploration Vision objectives. The goal of extending human presence in space is now the overriding purpose, although science objectives are also represented. The ISS should be an enabler for extending the human presence in space, along with pursuing related science objectives. NASA life sciences research moved from the Space Science Directorate fifteen years ago to a separate Office of Life and Microgravity Science and Applications. Once the Exploration Vision was announced, those lines of research were reconfigured and moved within the ESMD. So the life sciences endeavor is now living within a classic military command organization for engineering systems development and acquisition. Life sciences activities must, therefore, now be requirements-driven, rather than driven by a broad-based science imperative. As an example, the *Bioastronautics Roadmap* began by articulating some 55 risks to health and about 245 critical questions, which have since been narrowed down through the review process. Some of the risks included in the roadmap are well supported from the evidence and experience base, such as bone loss. In areas such as immunology, compromises to the immune system are known to exist, but the actual health-consequence risks are not known. Longitudinal studies such as the Longitudinal Study on Astronaut Health are needed to establish an evidence base for these risks. Another such area is cardiac arrhythmia. When the *Bioastronautics Roadmap* is transferred from its initial research context to the new requirements-driven engineering context, the priorities change. The engineers' first line of response is that the risks from these exposures can be engineered away, which is the first tenet of occupational health. However, the risk must be documented before it is accepted as the basis for a requirement driving the engineering of systems.

The Institute of Medicine (IOM) study of the medical care system as it was around 2000, published as S*afe Passage: Astronaut Care for Exploration Missions*,[2] included a recommendation to approach astronaut health through a methodology of occupational health monitoring and exposure control. The Office of the CHMO has been shifting its medical care in line with that recommendation. Dr. Williams described the rationale for applying exposure standards, like those used in occupational exposures, to protect astronaut health. Since the risks of bone loss or radiation exposure cannot be prevented completely, exposure standards and limits are needed. At present, the data from Skylab may be the best set of physiologic data available, and Dr. Williams advocated using the ISS to get better data before a Mars mission is undertaken. He described the standards development activity within the medical program, such as Spacecraft Maximum Allowable Concentration (SMAC) standards, and examples of standards development for controlling exposures on the ISS. These standards will be translated to systems requirements

[2] John R. Ball and Charles H. Evans, Jr., Editors, *Safe Passage: Astronaut Care for Exploration Missions.* Committee on Creating a Vision for Space Medicine During Travel Beyond Earth Orbit, Board on Health Sciences Policy, Institute of Medicine. Available online at http://books.nap.edu/catalog/10218.html.

by the ESMD. The Office of the CHMO is also creating risk mitigation standards for unique exposures, either as permissible exposure limits, permissible outcome limits based on estimates of outcome probability, or as fitness for duty standards. These principles are being applied in areas of potential health compromise, which would, if not mitigated, be considered as disease states when the exposed individual returns to the Earth environment. In the current engineering context with the primary objective of developing and acquiring systems, the standard has to be linked to a requirement if the intended exposure limit is to be reliably met.

Discussion: Col. Cabana asked if the integration of the human as a system within a system of systems generates standards for the human system, even from an engineering point of view. In the case of hearing and noise standards, for example, noise standards need to be engineered into the vehicle system, rather than trying to mitigate exposure with protective equipment worn by the crew or some other workaround. Dr. Williams agreed and expanded on the role of Human Systems Warrant Holders in ensuring that standards are met. Dr. Lomax noted that the requirements issue is linked with the problem of large uncertainties in health consequences, which makes standards setting difficult. Dr. Williams agreed and said that, with regard to human health, we are learning that a stepwise approach is needed to a human mission to Mars. It would be almost unconscionable, he said, not to use the ISS as part of this stepwise process. Col. Cabana asked about specific tests or research that needs to be done on the ISS. Dr. Williams said that his office has not identified specifics yet. He assumes that the ISS SRM and other activities in progress will contribute to defining those specifics. With respect to standards development, teams at the JSC are working on standards in the areas of bone atrophy, muscle loss, radiation dosage beyond LEO, neurosensory and neuromotor compromise, psychiatric and behavioral health, nutrition, and immunology. Another effort is to assess the ethics, practicality, and ground-based paradigms for deploying the best level or standard of medical care for a given category of exploration mission. Dr. Williams commented on some of the challenges in trying to develop reasonable and evidence-based standards in some of these health consequence areas. Standards will (1) establish a de facto declaration of acceptable risk and (2) serve as research targets to expand the evidence base.

RADM Betterton asked if standards will be formulated to address all of the risks identified in the *Bioastronautics Roadmap*. Dr. Williams replied that some of those risks are subsets of others. For each set of related risks for which an adequate evidence base exists, he would like to create a standard if the evidence supports a demonstrable risk. The paradigm for this approach is health protection through the promulgation of occupational health exposure standards. RADM Betterton then asked where, in the process of moving from identified risks to standards to requirements, is there a function for independent validation of the requirements. Dr. Williams said that a process has been constructed that emulates the OSHA standard-setting process. A draft standard developed by an internal group is reviewed by an external group that includes nationally recognized experts. The draft standard is also presented to the Astronaut Corps for comment. Then the draft standard undergoes a policy review for its broader implications including cost and consequences affecting other systems. When approved, the final standard is published as NASA policy through the auspices of the NASA Medical Policy Board, which the CHMO heads.

In the engineering realm, the Independent Technical Authority (ITA) owns the standards, and the same is true for health standards and the CHMO as Independent Health and Medical Authority. Dr. Williams described the conflict resolution process as it moves in parallel up the independent authorities organization and the programmatic organization. Setting up this parallel structure is difficult, particularly defining the boundaries and responsibilities of the independent authorities vis-a-vis their programmatic counterparts. For the ITA, the Chief Engineer has designated systems warrant holders and discipline warrant holders to review and act with the full authority of the Chief Engineer. These warrant holders are embedded in terms of where they work in a NASA Center's engineering organization, but their line of authority remains distinct from the program organization. Similarly the Independent Health and Medical Authority has health systems warrant holders and health discipline warrant holders. A health systems warrant officer is an expert in human health such as an aerospace medicine physician and is responsible for the human system as integrated into program systems. For exposures to the ground-based workforce, this role is played by OSHA or DOE as the standards owners, not the NASA Independent Health and Medical Authority. The role of the Office of the CHMO is to advise the health system warrant holders, but waiver authority will be vested in the human system warrant holder.

The relevance of the Independent Health and Medical Authority role and of health standards setting to the ISS is that there are more likely to be individuals exposed in the ISS environment than anywhere else. It is not clear that even an extended human presence on the Moon will be as extensive in terms of developing an evidence base. Dr. Williams gave examples of areas in which the ISS provides the best opportunity for test and development of standards. He stressed the importance of exploiting the ISS to its maximum research potential before decisions must be made on the acceptability of health risks in a mission to Mars.

Col. Cabana noted that a disadvantage for health and medical standards is that the human system is a highly flexible and adaptive system relative to engineered systems. So we typically find ways to adapt the human to the constraints of the engineered systems. Dr. Williams replied that it is also essential not to drive the engineered system toward a level of complexity that leads to catastrophic failure, which would defeat the fundamental purpose of protecting the lives of the crew. He used artificial gravity as an example of adding complexity to problems of spacecraft durability that might pose higher risks than the health hazards to be mitigated by artificial gravity. Whatever the final decision is on the ISS, Dr. Williams said, it is a powerful opportunity for understanding what will be needed to conduct extended spaceflight missions.

Col. Cabana asked who is defining the standards and what the time frame is for completing them. He said the committee needs to know the requirements on ISS activities (testing and research needs that can only be done on the ISS) to support the exposure standards development process. Dr. Williams replied that most of the requirements he discussed would, at the least, need validation in a long-duration space environment. The community will never know, for example, if a countermeasure for bone loss works in microgravity until it is validated in an analogue environment close to that of a Mars mission, including the mission duration. First drafts of the standards will be prepared by the end of April 2005. The ESMD will have the responsibility to derive system requirements from those standards and to fund the research and testing needed to validate the standards. Dr. Williams discussed with the committee the relationship between the CHMO staff and the ESMD in deriving requirements from the draft standards. A Human Systems Working Group has been formed at Headquarters under John Allen to consider everything from standards development to systems requirements and proposed lines of research. The working group comprises staff from the ESMD and the SOMD, with heavy representation from JSC.

Dr. Oman asked if any of the standards being developed are much more important than others in terms of the validation required. Dr. Williams said that could be the case, but it was difficult to answer with specifics. As the process continues, he will be prepared to take issues concerning mitigation of risks or opportunities to use the ISS up the chain of command, first to RADM Steidle and beyond that if necessary. Dr. Bartoe asked if validation activities would aim at validating a standard or validating the requirement(s) derived from it. Dr. Williams answered that, in cases of research on a countermeasure, the research would be to validate the countermeasure as meeting the standard. The standard will be considered validated at the end of the standard-setting process. However, lines of research could inform the development of other standards [or revision of existing standards] by augmenting the understanding of risk.

RADM Betterton asked about the continued validity over time (e.g., to 2035) of results from countermeasure validation on the ISS between now and 2016. Dr. Williams replied that new countermeasures and technology are likely to result from further advances, but the countermeasures validated now will still be valid. He related this point to the formulary of techniques and countermeasures usable by NASA flight surgeons.

Dr. Lomax asked if significant challenges, such as where additional research is needed, will be included in the CHMO report on draft standards. In response, Dr. Williams said that the standards-setting and requirements definition process differs from the traditional approach to clinical problem as exemplified by the national process for conducting health and medical research. This process has been applied before to specific physical hazards such as toxic substances, light, and noise (sound). But applying it to more complex health consequences, such as those in the behavioral health area, is really a pioneering effort. He and Dr. Lomax discussed issues in setting standards for conditions with no experience base in space, such as healing of bone fractures. In the area of standards of medical care, for example, Best Professional Opinion is likely to be used as the evidence base. Also discussed were areas of normal human physiological response to the microgravity environment that could be researched on the ISS. Dr. Williams said that the specifics of how such questions will be addressed will be a combined effort of those designing a specific research program with research protocols, solicitations for proposals, etc. Those specifics do not fall within the organizational responsibilities of the CHMO. Dr. Lomax asked about the role of animal research to complement human research. Dr. Williams agreed that animal research can fundamentally inform many lines of biomedical research and fundamental biology. If opportunity for research and testing on the ISS is limited, however, he will push for human health validation over animal experiments. Dr. Oman asked if there are any data points from animal experiments that are on the critical path to setting standards. Dr. Williams said that he did not have the details to answer directly. In further discussion with Dr. Oman on this question, he said that, looking down the list of standards being developed, there are areas where animal experiments would be helpful, but he did not see any where such experiments would be essential.

Dr. Sutton asked about issues of time lines and capability gaps, which might be useful for drafting the ISS SRM. He asked when the process for drafting and vetting the standards would be completed, just in terms of having a first round of standards. He also asked for any comments on a process for dealing with capability gaps. Dr. Williams replied that a full set of standards will be drafted, reviewed both internally and externally, and entered into NASA policy in a time frame of months. However, he expects the first draft of the standards to be very close to the final draft. First drafts will be out by the end of April or mid-May, and they can be used then to inform the research community on priority areas for potential ISS research. Areas of risks where validation in the microgravity environment of the ISS would be valuable include bone atrophy and loss, muscle strength, radiation in the context of exposures in a space environment with microgravity, neuromotor and neurosensory compromise, validation in the extended spaceflight environment of psychiatric and behavioral health results from ground experiments, validation of immunology ground studies, and nutrition in the context of microgravity. With respect to nutrition, the problems that have been encountered in extended spaceflights have been related to palatability and food selection. Dr. Williams said the effects of microgravity on those factors are poorly understood. He stressed that, if validation in the microgravity environment for any of these areas is not done by the time of a Mars mission, the health and medical staff will have to use the evidence base available. Although standards for inflight medical care are likely to be developed through medical ethics, policy, and similar ground-based discussion and thought, the implementation of the standard of care will require proof that they work as intended in extended exposures to a microgravity environment. With respect to the process for addressing capability gaps, the draft standards in the April–May time frame will inform the ESMD leadership of specific standards that the ESMD Requirements Division will need to address. As a substitute for this set of standards, the ESMD has been using a policy letter, published two months ago, which was extracted from a global description of the approach to crew health contained in the NASA Medical Policy Board handbook. The draft standards will be much more specific; they will have to be either met or waived.

Mr. Uhran asked for Dr. Williams' sense of how the research program that would be defined to address the draft standards would relate to the requirements that inform the current research program on human health. Dr. Williams thought that the standards would make the requirements more specific and help to target the resources available. The solicitation and selection process will be tighter and more focused than in the past, with greater weight placed on the relevance of a proposed research effort to mission requirements than on the scientific merit of the proposal. Mr. Uhran asked if there would be a substantial change from the current research program in the system and facility resources (upmass, crew time, etc.) required to conduct the necessary tests and experiments. Dr. Williams thinks the research selection process will be driven toward getting specifically useful results, while decreasing the requirements for upmass, numbers of subjects, and so on. The value of the available resources will have to be maximized.

RADM Betterton asked if Dr. Williams thinks he would be comfortable with the evidence base from such a research program at the time that decisions must be made for a Mars mission. Dr. Williams said that a definite answer is difficult because the CHMO job requires a balance of national imperatives and the capability at hand to protect the crew. The situation is not unlike decisions that have to be made in military settings. If the national imperative is strong enough to drive the mission, for whatever reason, then a CHMO can tolerate more uncertainty with regard to certifying a mission to proceed. If there is no imperative beyond a decision to attempt doing it, then the uncertainty parameters become tighter. By 2016, Dr. Williams said, if we are smart about what we do, he thinks a great deal can be done to satisfy the requirement set. If the ISS is used to its full capacity in this respect, the space medical community will have a pretty good knowledge base for protecting the crew of a Mars-duration mission. As we currently define "acceptable risk," the risks would be acceptable. RADM Betterton noted that military missions are typically event-driven, not calendar-driven. He asked what event, putting aside the calendar data of 2016, would provide an adequate level of confidence. Dr. Williams replied that his marker for acceptable risk is the risk considered acceptable by standards-setters in other areas—for example the EPA and OSHA. Protection is never absolute, so a standard always protects to some level. Ideally, one should be able to protect space mission crews to the same extent that workers on Earth are protected. Historically, however, we have accepted more risk in space missions than we do on the ground. If we did not, we would not have done the missions. As a personal opinion, Dr. Williams said he would have difficulty in countenancing a long-duration mission to Mars if the ISS were ignored as a venue for doing more in the areas he had discussed.

In thanking Dr. Williams for meeting with the committee, Col. Cabana acknowledged the tremendous job done by the CHMO's crews in keeping astronauts flying. In that vein, Dr. Williams suggested that the SRM Committee hear from Jeff Davis at JSC on issues related to astronaut health and fitness.

ISS Roadmap Discussion

Mr. Uhran asked committee members for their perceptions on critical elements that need to be addressed in the roadmap and report. A critical element might be a decision, enabling capability, or even a contextual factor for a decision. For example, the ISS roadmap has to address the impact of the health standards described by Dr. Williams. It must address, as a contextual factor, national educational policy and the role of space exploration in stimulating student and teacher interest in science and technology. Other issues are the opportunity costs if the ISS were not used to address major exploration issues and the research and other investigations that can be conducted within the margin of available resources. Requirements are never static and will remain dynamic over the life of a program, Mr. Uhran said. Therefore the roadmap needs to reflect the dynamic nature of ISS program requirements, such as the right times to revisit and reevaluate them. A chronic problem in the ISS program has been the identification of specific missions to be conducted. A mission could be a set of experiments or a research program to satisfy the bone loss countermeasures objective. Dr. Lomax commented that ISS expeditions with a specific theme are already being planned, such as the expedition focusing on bone and joint issues next year. Mr. Uhran said that he was thinking about a mission/research program more as a specific longitudinal strategy extending over several increments than a dedicated ISS increment. He suggested that there should be three types of mission sets: “human system” mission sets, sets of spacecraft systems technology and engineering demonstrations, and space operations mission sets. If the opportunity cost argument is persuasive and additional missions of one of these types can be done on the margin [of available resources], there may be opportunity for additional families of mission sets having secondary or tertiary priority.

Robert Cabana said that much of ISS science in the past was done through grants. If there is insufficient funding for the science, the program may be able to offer the on-board resources to allow research funded by other means to be performed on the ISS. Dr. Lomax added that a new model would be needed, in that case, to resolve the competition for onboard space [and other resources] between the commercial utilization of the ISS and space medicine research. Committee members discussed marginal utilization of ISS and Shuttle capacities by commercial and research users. One comment was that a process for allocation among competing utilization claims is needed, to which the ISS Program adheres for multiyear periods and commitments.

Charles Walker suggested critical elements for (1) life support systems validation in the spaceflight environment and (2) transferring the programmatic, technical, and management skill base (human capital) from ISS programs to exploration programs. The levels for transfer of the skill base include the levels represented by participants in the boards that advise the ISS Program Manager, those with experience in managing the interests of multiple stakeholders, and the engineering skills base to be translated to exploration operations. Col. Cabana said that the ESMD management has brought in its own model for program management. The committee discussed the need for sustaining the transfer of the skills base in the contractor community, the aging of the engineering and technical community, intergenerational transfer of the skills base, and the transfer of the technical skill base from ISS operations to exploration mission operations.

Charles Oman said his list of critical elements included the requirements [related to health and human performance] and when those requirements will be known. What are the problems that must be solved to protect the life of crews? The transportation options after Shuttle are a critical element for what research and testing can be done on the ISS. Another element for the committee to consider is what happens to the ISS after 2016: will there be an international operating authority for the ISS or perhaps commercial prospects such as tourism? What must be done to transition NASA facilities to this post-2016 mode of operation? Dr. Oman liked the format used in the roadmap graphics presented on Thursday by Steve Cook, in which programmatic milestones are linked to decision points, which are drive by critical questions. The current discussion, he said, appears to be identifying some of those critical questions. The committee needs to identify external factors that could significantly alter implementation of the roadmap. It should consider how to make the roadmap robust to such changes.

Jeffrey Sutton said he would like to work on the integration of the ISS SRM with other roadmaps, using the Exploration Transportation Systems SRM as a model. For example, there might be a detailed time line for a specific campaign, starting from the current state, with decision points and pathways branching from the decision points. Activities that must be done on the ISS could be distinguished from those that could be done in other analog environments. The medical research campaigns should be presented at a fairly high level. Mr. Uhran added that the human support technology, exploration systems technology, and operations demonstrations could each be a separate page, with another level of decomposition below each of these three category-level roadmaps. Linkages across the pages should be indicated.

Robert Cabana listed the following critical elements, which he placed under the general heading of how to use the ISS to further the exploration focus. (1) What are the requirements for the human system, for engineering proof and development of systems, and operational schemes for exploration that could be proven on the ISS? (2) What are lessons learned from the ISS on integration of large complex structures (links with capturing the knowledge base)? (3) The committee should be briefed on the science accomplished so far on the ISS. (4) What is the plan for controlled deorbit of the ISS when that decision is made? (Find the requirements and then figure out how to meet them.)

Thomas Betterton began with the general observation that there appear to be three or four NASAs, represented by the mission directorates, with serious communication gaps between them. The mission directorates need to be drawn together in the requirements process and the implementation process. That fundamental problem could be exacerbated by having a set of independent roadmaps. He then listed the following critical elements: (1) a requirements process that incorporates the necessary flexibility and goes across directorates, (2) a prioritized list of the exploration requirements that can be satisfied by the ISS, (3) an assessment of the extent to which the ISS baseline program will satisfy the requirements, perhaps to be done by this committee, and (4) alternative scenarios for satisfying the requirements. RADM Betterton also advocated moving from a calendar-driven flow of milestones to an event-driven approach for such milestones as a post-Shuttle crew and cargo capacity and the long-term use and disposition of the ISS. With respect to the latter, he foresees a continuing value in maintaining a microgravity environment in LEO. An immediate next step for the SRM Committee should be a review and decision on the set of derived ISS objectives drafted by Dr. Bartoe. The set needs additional work by the full committee.

John-David Bartoe began his list of critical elements with (1) the need for a list of measurable objectives for the ISS. The roadmap should show the intersects and decision points for when capabilities are needed. It should propose a process for getting to a set of measurable objectives, as it is unclear whether the committee will be able to provide a definitive or final set of such objectives. (2) The committee has spent considerable time on the human element and the countermeasures element. There is still a lot to understand about technology development efforts, and they should have equal stature in the roadmap report with the human health and countermeasures aspects. (3) The committee should ask SOMD to help with defining operations requirements. For example, do we know enough today to run a vehicle to Mars and back, or does the engineering staff need to learn how to do this while managing operations on board the ISS?

There could be a set of SOMD requirements for work to be done on the ISS, not just ESMD requirements for operations. (4) The transportation solutions need to deal with the situation of a limited opportunity to use the ISS before this asset is no longer available. (5) There should be some "Ready for Mars?" decision boxes on the roadmap, as were incorporated in pathways of the Robotic and Human Lunar Exploration SRM [briefed by Michael Hawes]. These decision points should address whether we are ready to go to Mars, in terms of everything that needs to be learned on the ISS beforehand. (6) The SRM Committee should be bold about intersects with other roadmaps and not rely on other SRM committees to tell this committee what they want. The roadmap should address the likelihood that new and unexpected mission sets will emerge. Dr. Bartoe thinks that, as the termination of ISS operations approaches, there will be an increasing interest in using it. (7) The international objectives for the ISS need to be addressed in the roadmap, including international objectives stated in the President's Vision for Space Exploration. (8) The last item on his list is the issue of corporate knowledge and transfer of knowledge and skills to the next generation of operating organizations. There is not yet a model for doing this in the engineering community as it occurs in the science community. The closest positive example is in mission control training.

William Bastedo listed the following thoughts and comments: (1) Does the SRM Committee as a group need to take a stand on the relevance of the ISS to the future of NASA? Is it on the critical path or not? The committee's duty is to put its thoughts on that into the report. (2) Requirements will not be static, either for ISS or other components for exploration. NASA needs to think in terms of mission sets that get updated on the basis of new learning and decisions over time about areas such as the transportation architecture or biomedical issues. (3) The ISS should be viewed not only as a tool for getting to the Moon and Mars but as an entity that has multiple stakeholders that will drive requirements for what will be done on it. The ESMD is only one of these stakeholders. Other stakeholders are education and outreach, research, SOMD, and the Department of State (the ISS role in foreign policy). So the committee might think about broadening the list of decision points or inputs to capture the role of the ISS as an asset for a broader cross-section of the Agency. (4) This committee will need to produce something like the Exploration Transportation Systems roadmap, but with three major decision points or types of decisions: (a) At intervals, there should be a decision point for the need to stop and think about whether the path is still the right one, based on current knowledge. There should be a series of such decision points at some interval, perhaps every two years. (b) Decisions are needed about the cargo resupply requirement that starts in 2010 with the retirement of Shuttle. Those decisions are probably needed in the 2007 time frame. (c) Around 2012 to 2013, a serious effort will be needed on what comes after 2016. That decision should be based on what is known then, not what is known today. Some questions, such as deorbiting, can be addressed by studies in the near term, but the final decision on implementing that path comes later. (5) Related to point (3) above, there are five categories for what the ISS can provide: (a) a research facility to buy down risk for the effects of long duration spaceflight on human health, (b) a testbed for technology maturation to support exploration objectives, (c) a prototype developer of next-generation hardware (per Mr. Gerstenmaier's suggestions on Thursday), (d) human capital preservation and a lessons-learned database, and (e) an operational testbed. With respect to the prototype developer role, Dr. Bartoe gave an example of lessons learned from flying a full-scale ISS rack on SpaceHab.

Terri Lomax offered the following comments: (1) There are no fixed objectives for the ISS. They will continue to change with time. The roadmap should provide the larger picture of key roles and objectives with key decision points, similar to the format used in the Exploration Transportation Systems SRM. (2) Among the critical questions in the Exploration Transportation Systems SRM are some that also apply to the ISS, such as potential roles for international partners beyond just fulfilling past commitments. NASA needs new ways of working with them and providing opportunity for their research real estate on the ISS to contribute to NASA research needs. (3) A new model is needed for commercial utilization of the ISS. (4) The "McMurdo" model suggested for a lunar base may also be applicable to the ISS, as a base used by multiple customers. (5) The ISS Program needs an executable solution in which requirements, cost, and schedule are aligned. (6) Are different launch vehicles needed for cargo versus crew, particularly after 2010? How many crew members will be onboard the ISS? What is the duration of increments? With respect to this item, Col. Cabana said the ISS will have capacity and budget for six crew in 2009. Mr. Uhran said that the completed ESMD requirements will be reviewed to determine the ISS crew size required to meet the research and testing activities to be done on the ISS. (8) Life support and habitation issues need to be addressed, as do other spacecraft capability issues.

Dr. Bartoe agreed with the point that a determinate set of objectives need not be written down as part of the ISS roadmap. He agreed with the point that there are event-driven decision points at which objectives should be decided or reexamined. ISS utilization capability is booked for at least the next 18 months, and there is a time lag from decisions on utilization to when those decisions can be implemented. Dr. Oman asked if it was in the committee's purview to suggest an advisory structure for implementation of the roadmap, like the Space Station Utilization Advisory Subcommittee (SSUAS). Mr. Uhran agreed with the value of an advisory function for a multipurpose facility like the ISS, but suggested that the views of the new administrator on an advisory structure be heard first.

Marlene MacLeish provided comments on E/PO issues relevant to the ISS SRM. The E/PO SRM Committee has set up liaisons to pull information from the SRMs. That committee wants to know about educational opportunities on the ISS and whether they are near, mid, or long term. Topics of interest include formal and informal education, public outreach, and workforce-related impacts. The E/PO SRM Committee has been tasked to address ways that E/PO objectives can be stated at the highest strategic levels and sustained over several decades. That committee is expecting input from this committee on what the ISS SRM needs from NASA E/PO programs. What the NASA E/PO programs do in formal education needs to be calibrated against national educational standards. That committee is also seeking new paradigms for E/PO: How to interest the best minds in space exploration and the related science and technology? How to engage teachers in new ways of teaching?

Mr. Walker suggested that the ISS could serve as a platform for qualifying new international partners, such as China, in space exploration. The committee discussed a potential role for the ISS as a global field center for spacefaring nations. For this role, it would not have to be run as a government enterprise. The committee discussed the pull on ISS utilization from the Mars SRM.

Next, the committee discussed whether to have its third formal meeting in mid-May, in association with the Shuttle RTF launch. The members agreed not to have a formal meeting at that time and to meet instead in June.

ISS Roadmap Drafting

Mr. Uhran presented a table of interdependencies between the ISS Program and programs in other SRMS, as identified by the other SRM Committees or by staff of this committee. A second table listed interdependencies with the CRMs. The committee discussed how interdependencies will be communicated between SRM committees. Mr. Uhran noted that the timing for producing some of the SRMs is under review.

The ESMD report on exploration system requirements is currently being reviewed by the SOMD, after which the report will go to the Associate Administrators and the new NASA Administrator.

The committee turned to review and revision of Dr. Bartoe's draft map of the traceability of ISS objectives to statements of NASA's vision, mission, goals, and objectives. The committee agreed to use an approach like that in the Lunar Exploration SRM, in which Exploration Vision objectives called out and related to a set of specific lunar exploration objectives, which provide the guiding framework for that roadmap. In this context, the members discussed which national and NASA documents to emphasize for the traceability of ISS SRM objectives. After discussion, the committee agreed that Dr. Bartoe will revise the draft traceability map in response to the committee's comments. There was further discussion of the factors driving 2010 as the date for completion of ISS assembly and 2016 as the termination date for NASA support of the ISS.

Mr. Uhran presented several draft notional charts on ISS research prioritization. The charts' format was based on the research planning approach being advocated by the ESMD. Each chart graphically depicts a measure of the need for ISS on one axis and a measure of projected mission benefit on the other. In the sample charts discussed, the dots representing research projects/investigations were notional only. On a budget-driven approach to ISS utilization, the research selected would require a high level of both mission benefit and need for the ISS. If ISS utilization were priority-driven, all items with high mission benefit would be selected. The committee discussed this way of presenting the research prioritization trade space and alternatives. They also asked how the ESMD research plan for the ISS using this approach will be vetted within the Agency. One suggested response was that the ISS SRM Committee provide its own estimation of where research items fall with respect to mission benefit and the need to conduct the research on the ISS. Another point was that the space operations area of ISS utilization should be represented. The members discussed how the committee might do its own assessment of where the research items are located in the trade space. Mr. Uhran noted that several of the points made by members during the round-robin discussion earlier in the day would be relevant to a discussion of the trade space for research planning and the basic approach that should be used for ISS research selection. The committee agreed with a suggestion that analyses of costs for research options items is needed to make prioritization decisions that weigh opportunities to conduct research with low marginal cost but substantial mission benefit.

Mr. Uhran and RADM Betterton led a discussion of draft charts for the roadmap, which RADM Betterton had prepared. The charts represent notional contributions from the ISS baseline program and from two alternative scenarios to the five exploration spirals. RADM Betterton said that the take-home point of the draft charts is that the ISS baseline program will have fairly significant contributions to exploration spirals 1 and 2, with little contribution in the outyears beyond 2020. The first alternative shows that ISS applicability could be improved by maintaining Shuttle-level crew and cargo capability throughout the lifetime of the ISS. Its applicability to exploration objectives could be improved even more by maintaining an ISS-like capability at least until a permanent lunar presence is established (second alternative). He stressed that the pathways and milestones in the draft viewcharts are notional and might change in light of detailed analyses. The committee discussed whether the contribution levels shown in the draft charts were correct for specific types of engineering and human system support technology demonstrations. The basis for the 2016 date was discussed, as was the timing and basis for a decision on extending ISS utilization beyond 2016.

The lifetime of technology demonstrations on the ISS relative to the likely timing of a human Mars mission was discussed. The committee discussed risk reduction for human Mars missions through testing of systems in extended space flight. If not completed on the ISS, this testing will need to be done another way. Other topics discussed were the benefits and costs of ISS-based testing relative to other test options and the relevance of the ISS as a testbed for extended duration missions in low to zero gravity. Various changes and additions to the draft charts by RADM Betterton were discussed and agreed upon. Mr. Uhran suggested that each of the three bars—exploration systems research and technology (ESRT), human systems research and technology (HSRT), and operations demonstrations (OPS)-— in the baseline program chart should be expanded in a separate chart to show major mission sets in that area. The Lunar Exploration roadmap charts will be used as a format template. RADM Betterton will revise the top-level chart in response to the committee's comments. Dr. Lomax will draft the expansion chart for ESRT. Mr. Uhran and Col. Cabana will draft the expansion chart for Operations Demonstrations, and Dr. Sutton and Dr. Oman will do the same for HSRT. The summary chart, which shows the applicability of ISS activities to the exploration spirals, will be used as a roll-up graphic that follows after the charts for the three categories of mission sets.

The committee discussed the chart of roadmap decision points chart drafted by Mr. Uhran and how to integrate the decision points with the other draft roadmap charts. Mr. Bastedo said it would be useful to hear from the Mars SRM Committee about the potential pull on ISS-based demonstration and research from Mars roadmap. Mr. Uhran suggested that the meeting dates for the other SRM Committees be distributed to the members of this committee so that members can attend and interact with the other committees.

Wrap Up Discussion and Planning

Mr. Uhran noted two events that will determine the schedule for the committee's work on the ISS SRM. One is the August 15 meeting in La Jolla, California, to finalize the FY 2007 budget. The second event is the action taken by the new Administrator on what he wants from this committee and the strategic roadmapping process. The members discussed having an interim product for the new Administrator in the near term and what the central messages should be. Another topic was whether and how to make the case that the ISS is on the critical path for achieving exploration objectives. The committee agreed on the alternative of a brief progress report to Mary Kicza, which the cochairs will draft. The meeting was adjourned at 3:00 p.m. MDT.

International Space Station (ISS) Strategic Roadmap Committee
April 7–8, 2005
The Magnolia Hotel
Denver, Colorado
Agenda

Thursday – April 7, 2005

10:00am	Opening Remarks *Co-Chairs*	T. Betterton R. Cabana
10:15am	NASA and ISS Risk Management Approach *Space Operations Mission Directorate, HQ*	T. Gallina
11:00am	Exploration Transportation System Roadmap *Exploration Systems Mission Directorate, HQ*	S. Cook
12 noon	Lunch	
12:30pm	Robotic & Human Lunar Exploration Roadmap *Exploration Systems Mission Directorate, HQ*	W. M. Hawes
1:30pm	Human Health and Support Systems Capability Roadmap *Bioastronautics Exploration Research & Technology Office, JSC*	J. Charles
2:30pm	ISS Education Outreach *ISS Program Office, JSC*	W.F. Dillon
3:30pm	ISS Capabilities for Exploration *ISS Program Office, JSC*	W. Gerstenmaier
4:30pm	Discussion	Committee
5:30pm	Adjourn	
6:30pm	Dinner	

Friday, April 8, 2005

8:30am	Opening Remarks	M. Uhran
9:00am	NASA Chief Medical Officer Perspective	R. Williams
9:30am	ISS Roadmap Discussion	Committee
12 noon	Lunch	
12:30pm	ISS Roadmap Drafting	Committee
4:00pm	Wrap Up Discussion and Planning	Committee
5:00pm	Adjourn	

International Space Station Strategic Roadmap Committee
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MEETING ATTENDEES

Betterton, Thomas, *co-chair*	Naval Postgraduate School
Cabana, Robert, *co-chair*	NASA/JSC
Uhran, Mark, *co-chair*	NASA Headquarters
Bartoe, John-David	NASA/JSC
Bastedo, William	Booz Allen Hamilton
Lomax, Terri	NASA Headquarters
Oman, Charles	Massachusetts Institute of Technology
Sutton, Jeffrey	National Space Biomedical Research Institute
Walker, Charles	Boeing Aerospace Corporation
Lembeck, Michael	NASA Headquarters (ex officio)
Williams, Richard	NASA Headquarters (ex officio)
MacLeish, Marlene	Morehouse School of Medicine (ex officio)
Edgington, Susan, *Designated Federal Official*	NASA Headquarters
Charles, John	NASA/JSC
Cook, Steve	NASA/.MSFC
Dillon, Ford	NASA/JSC
Gallina, Tony	NASA Headquarters
Hawes, Michael	NASA Headquarters
Kreykenbohm, Barbara	NASA Headquarters
Lugg, Desmond	NASA Headquarters
McKay, Meredith	NASA Headquarters
Cantuyn, Stefanie	BioSense–CU
Foley, Kevin	Boeing–Houston
Katt, Robert	INFONETIC
Selmarten, John	United Space Alliance
Stodiech, Louis	University of Colorado

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LIST OF PRESENTATION MATERIAL[3]

1. Tony Gallina, ISS Staff, Space Operations Mission Directorate. *NASA Risk Management Requirements Flow Down*.
2. Tony Gallina, ISS Staff, Space Operations Mission Directorate. *ISS Risk Management Activity*.
3. Steve Cook, Exploration Systems Management Directorate. *Exploration Transportation Roadmap. Overview to the ISS Roadmap Committee.* April 7, 2005.
4. Michael Hawes, Space Operations Mission Directorate. *Lunar Strategic Roadmap Status*. *Briefing to the ISS Strategic Roadmap Committee*. April 2005.
5. John Charles and Dennis Grounds, NASA Johnson Space Center. *Human Health Risk Management Approach: Space Medicine, Bioastronautics Roadmap, and Risk Quantification.* April 7, 2005.
6. John Charles, NASA Johnson Space Center. *Human Health and Support Systems Capability Roadmap Progress Review.* (Extracted from original presentation by Dennis Grounds and Al Boehm to the National Academy of Engineering on March 17, 2005).
7. Ford Dillon, ISS External Relations Office. *ISS Education Outreach*. April 7-8, 2005.
8. William H. Gerstenmaier, ISS Program Manager. *International Space Station Capabilities for Exploration*. April 7, 2005.
9. International Space Station Program Office and Office of the International Space Station Program Scientist. *Synopsis of Mission and Experiments. 10 Soyuz/Expedition 11 Launch. 9 Soyuz/Expedition 10 Return.* April 2005.

[3] Presentation and other materials distributed at the meeting are on file at NASA Headquarters, Space Operations Mission Directorate, Washington, DC 20546.